

Operator Training: NSRL Energy and Species Change

Created by P. Sampson

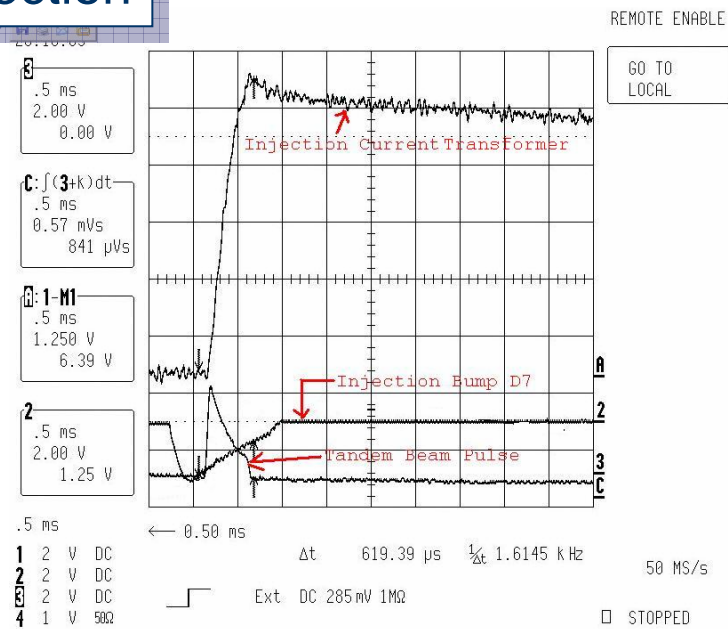
*Modified by L. Hammons
May 2007*

Prerequisites

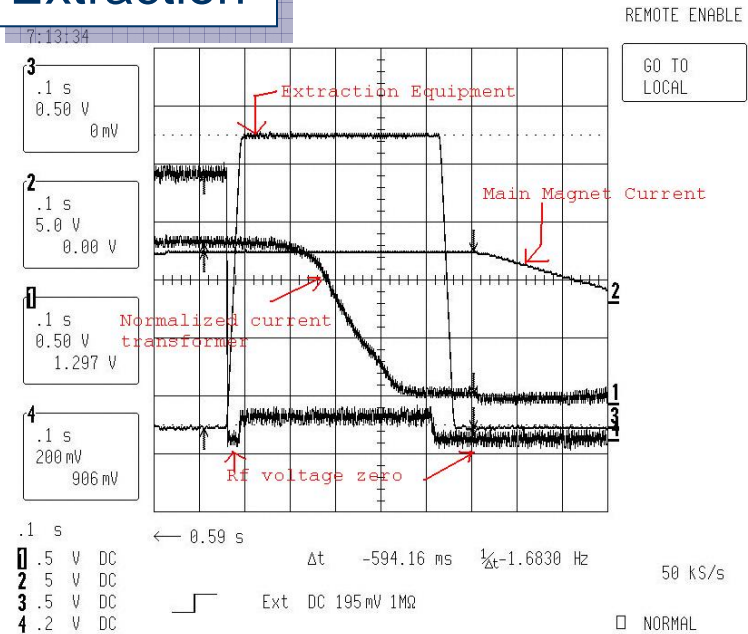
- This module assumes that the Booster is running properly for a given energy and species
- Features of “proper” operations include:
 - Acceptable injection, acceleration and extraction efficiencies
 - Acceptable spill parameters
 - Acceptable optics

Review of Timing Features

Injection



Extraction

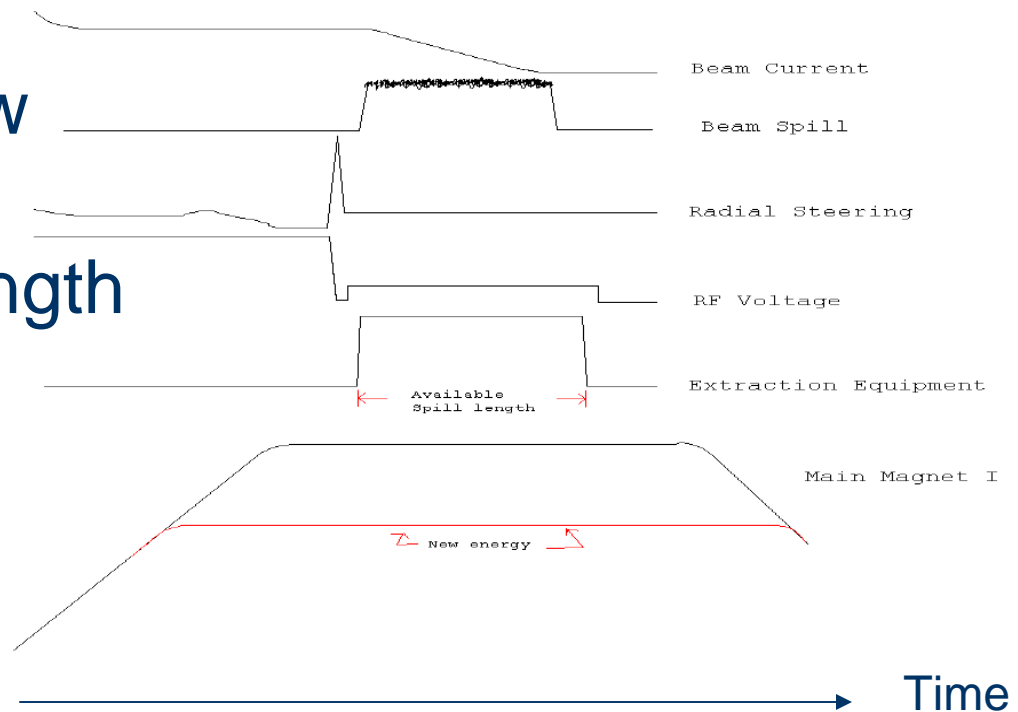


Energy and Species Changes

- Some elements of machine operation will remain unchanged
- Accelerated beam operation may be left on during process
- Energy and Species changes require following alterations:
 - Scaling of the magnetic elements to new beam momentum (rigidity) including:
 - Setting new user parameters in SuperMan
 - This is an extremely important first step for species changes!
 - Booster Main Magnet Function
 - Possibly spill servo function
 - Scaling of main magnet nominally handled in software
 - Tune and Chromaticity Functions
 - Transport Elements (R-line)
 - Most easily handled through use of R-line magnet manager
 - Extraction Bumps
 - Extraction Septa
 - Correction Elements
 - D6 corrector coil
 - D6 single bump
 - C3 Inflector (if necessary)
 - Adjustment of the RF parameters for new species and energy in BoosterBeamControl
 - Most energy and species changes have preset parameters

Extraction Timing

- Extraction timing remains the same for energy changes
- Flattop may grow or shrink, but available spill length remains same



Magnetic Changes

- Magnets are scaled by the ratio of the rigidities of the old and new species
- MMPS functions are scaled by the same factor
 - This feature is automated in the software
- Resonant sextupole currents should be scaled by the ratio of the square roots of the rigidities

Magnetic Rigidity

- The force on a moving, charged particle given by the Lorentz force:

$$F = evB = \frac{mv^2}{\rho}$$

- This can be rearranged:

$$B\rho = \frac{mv}{e} = \frac{p}{e}$$

- $B\rho$ is called the **magnetic rigidity**, and if we put in all the correct units we obtain:

$$B\rho = 33.356 \cdot p \text{ [KG}\cdot\text{m]} = 3.3356 \cdot p \text{ [T}\cdot\text{m]} \quad (\text{if } p \text{ is in [GeV/c])}$$

Rigidity and Dipole Fields

- A dipole with a uniform dipolar field deviates a particle by an angle θ
- The angle θ can be calculated:

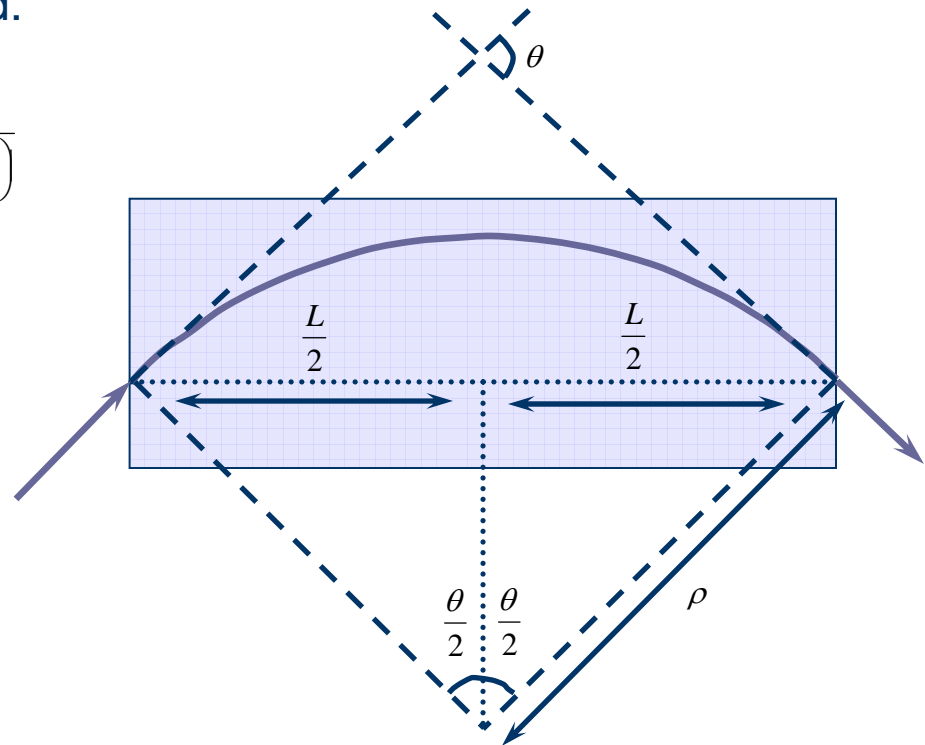
$$\sin\left(\frac{\Theta}{2}\right) = \frac{L}{2\rho} = \frac{1}{2} \frac{LB}{(B\rho)}$$

- If θ is small:

$$\sin\left(\frac{\Theta}{2}\right) = \frac{\Theta}{2}$$

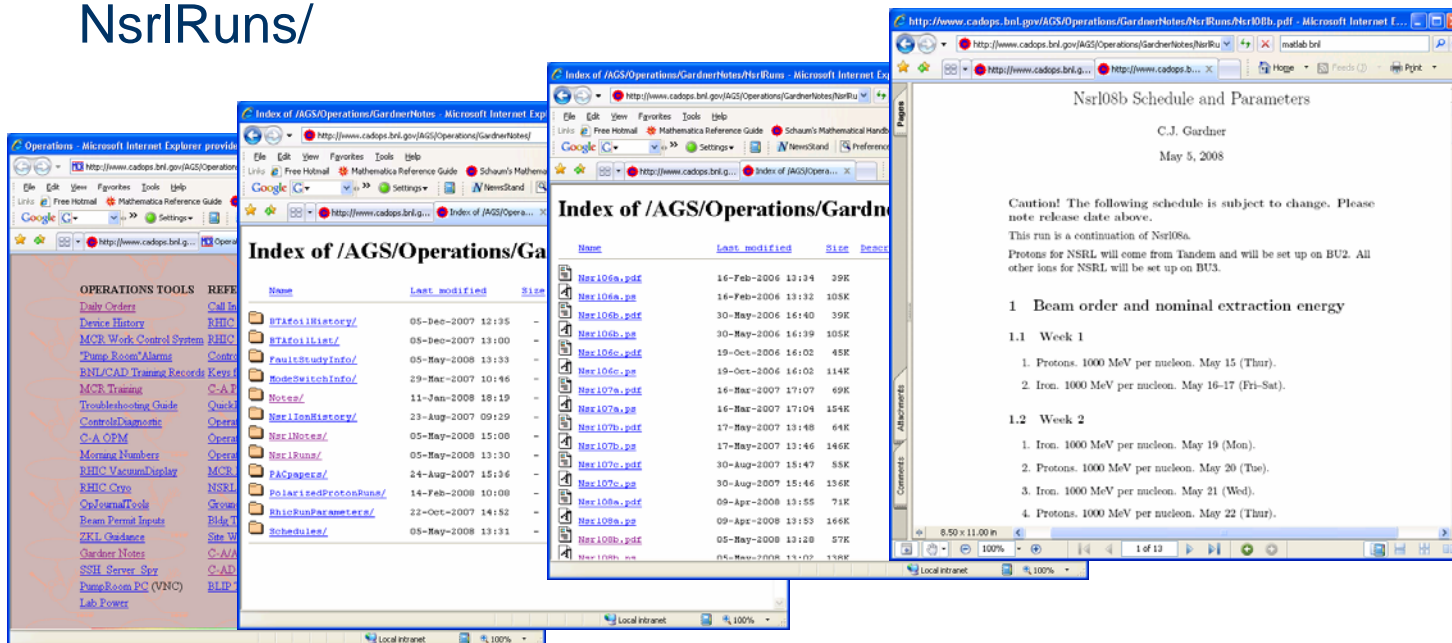
- So we can write:

$$\Theta = \frac{LB}{(B\rho)}$$



Finding Rigidities

- Rigidities are published in the 'Gardner notes' for each NSRL run
 - <http://www.cadops.bnl.gov/AGS/Operations/GardnerNotes/NsrlRuns/>



Using the Gardner Notes

Beams and Extraction Energies

1 Beam order and nominal extraction energy

1.1 Week 1

1. Protons. 1000 MeV per nucleon. May 15 (Thur).
2. Iron. 1000 MeV per nucleon. May 16–17 (Fri–Sat).

1.2 Week 2

1. Iron. 1000 MeV per nucleon. May 19 (Mon).
2. Protons. 1000 MeV per nucleon. May 20 (Tue).
3. Iron. 1000 MeV per nucleon. May 21 (Wed).
4. Protons. 1000 MeV per nucleon. May 22 (Thur).

1.3 Week 3

1. Iron. 1000 MeV per nucleon. May 27–28 (Tue–Wed).
2. Protons. 1000 MeV per nucleon. May 29 (Thur).

- Energies and rigidities are listed and readily accessible through the notes

Injection Parameters

Table 3: Titanium and Iron Parameters at Booster Injection

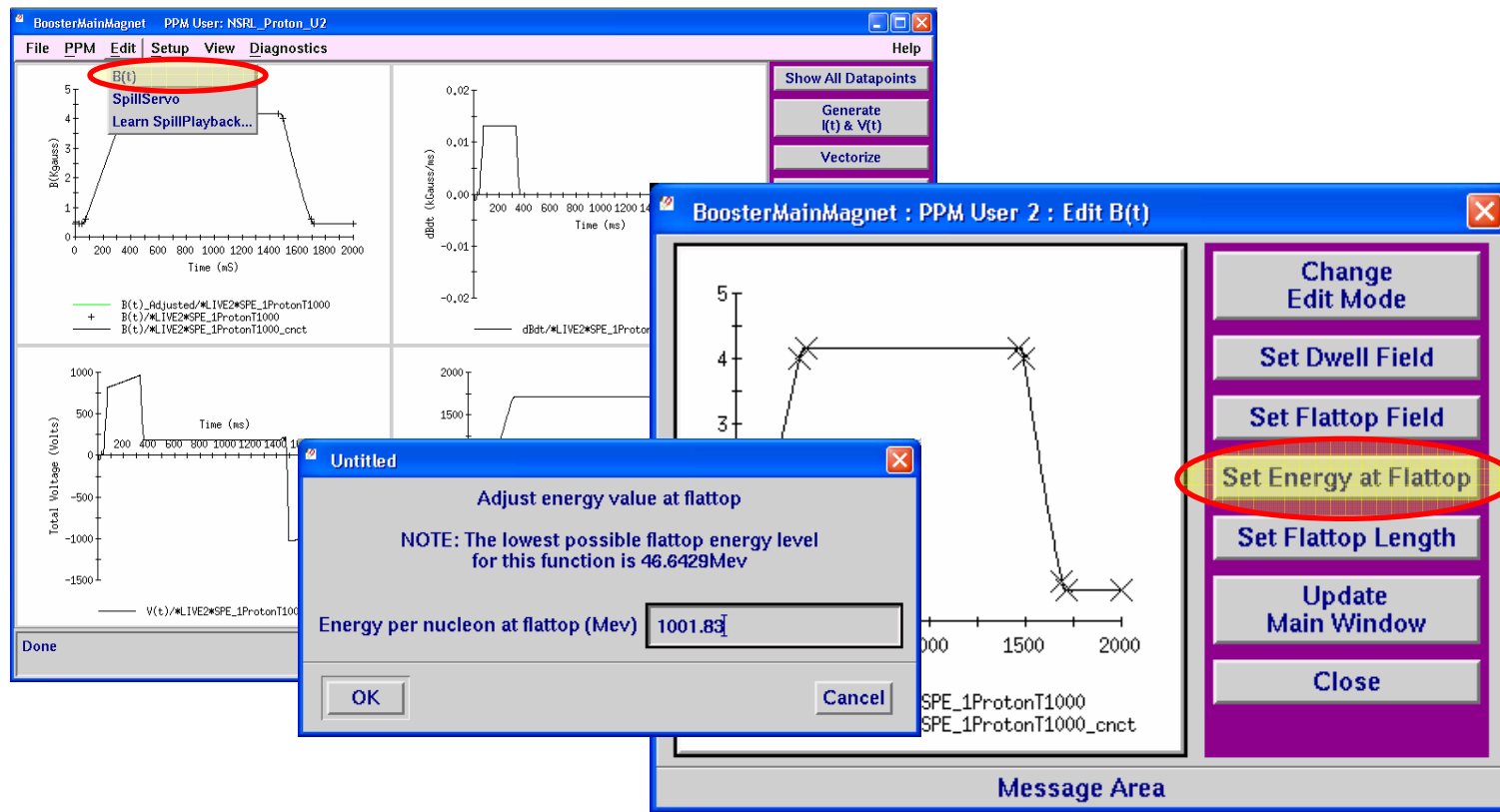
Parameter	Ti ¹⁸⁺	Fe ²⁰⁺	Unit
Protons	22	26	
Nucleons	48	56	
mc^2	44.6540277	52.0928437	GeV
Archive Date	28–29 Jun 07	October 07	
11DH1 NMR Probe	4364.1	4364.1	Gauss
hf	358.0563	341.131	kHz
h	3	3	
$T = 1/f$	8.3786	8.79427	μ s
Kinetic Energy W	144.7817	153.2415	MeV
$B\rho$	0.6669	0.6669	Tm
$B\rho/\rho$	480.974	480.974	Gauss
Booster Hall Probe	–	453.4	Gauss
Booster Gauss Clock	–	23.5	Gauss
Injection Field H	476.9	476.9	Gauss
Inflector Setpoint V_S	–	29.605	kV
Inflector Predicted V_I	31.235	29.759	kV

Extraction Parameters

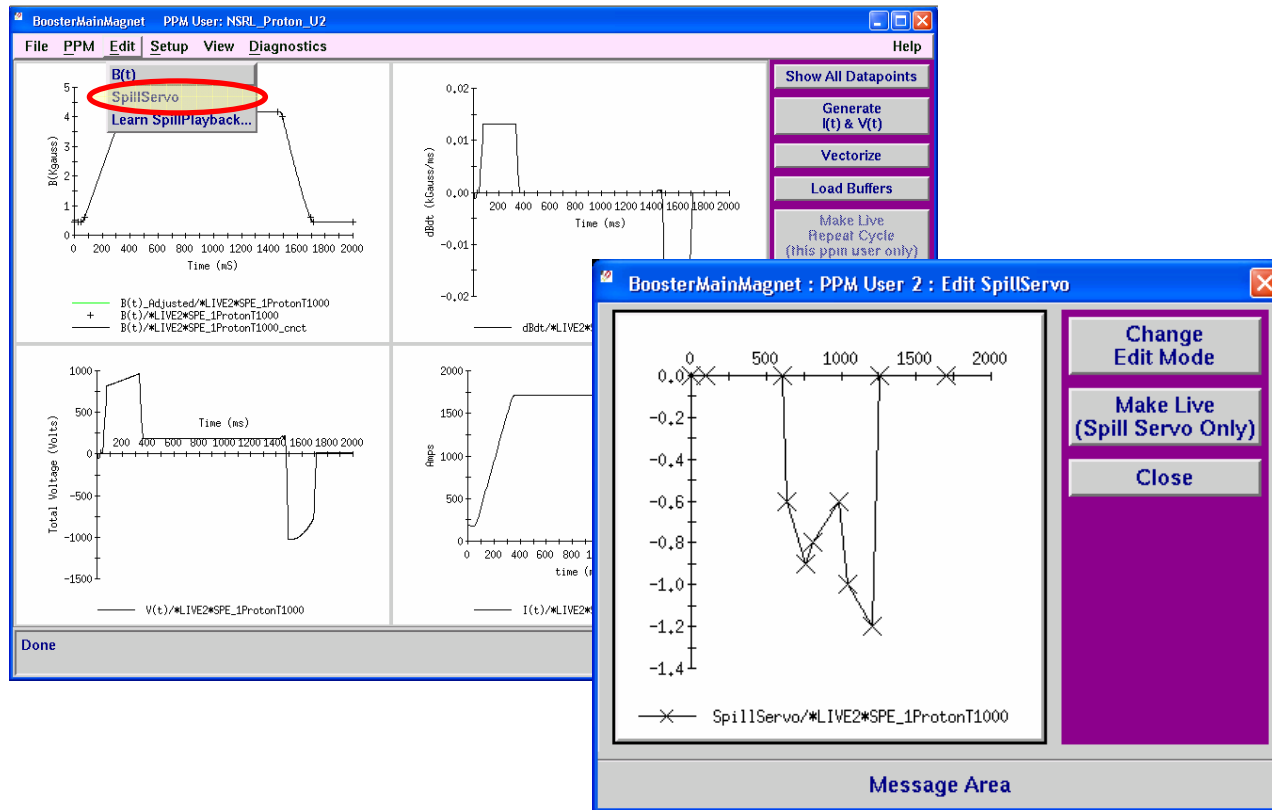
Table 9: Titanium Parameters at Booster Extraction

Parameter	Ti ¹⁸⁺	Ti ¹⁸⁺	Unit
mc^2	44.6540277	44.6540277	GeV
Archive Date	28–29 Jun 07	28–29 Jun 07	
hf	3.9054238	3.912198	MHz
h	3	3	
$T = 1/f$	0.768162	0.766832	μ s
Kinetic E per Nucleon	1000	1011.1732	MeV
$B\rho$	15.0444189475	15.15774913	Tm
$B\rho/\rho$	10850.18	10931.91	Gauss
Magnetic Field Setpoint	–	11100	Gauss
MM Current Setpoint	–	4663	Amps

Scaling the Main Magnet

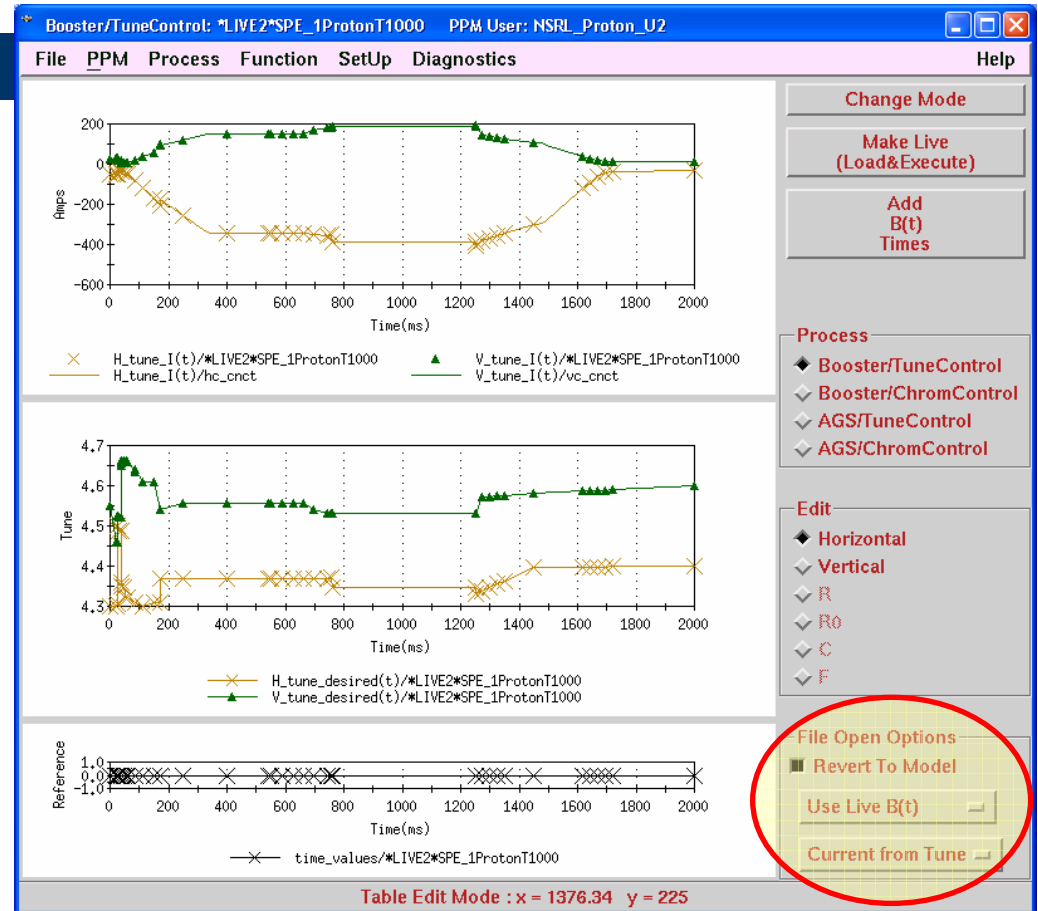


Adjusting the Spill Servo



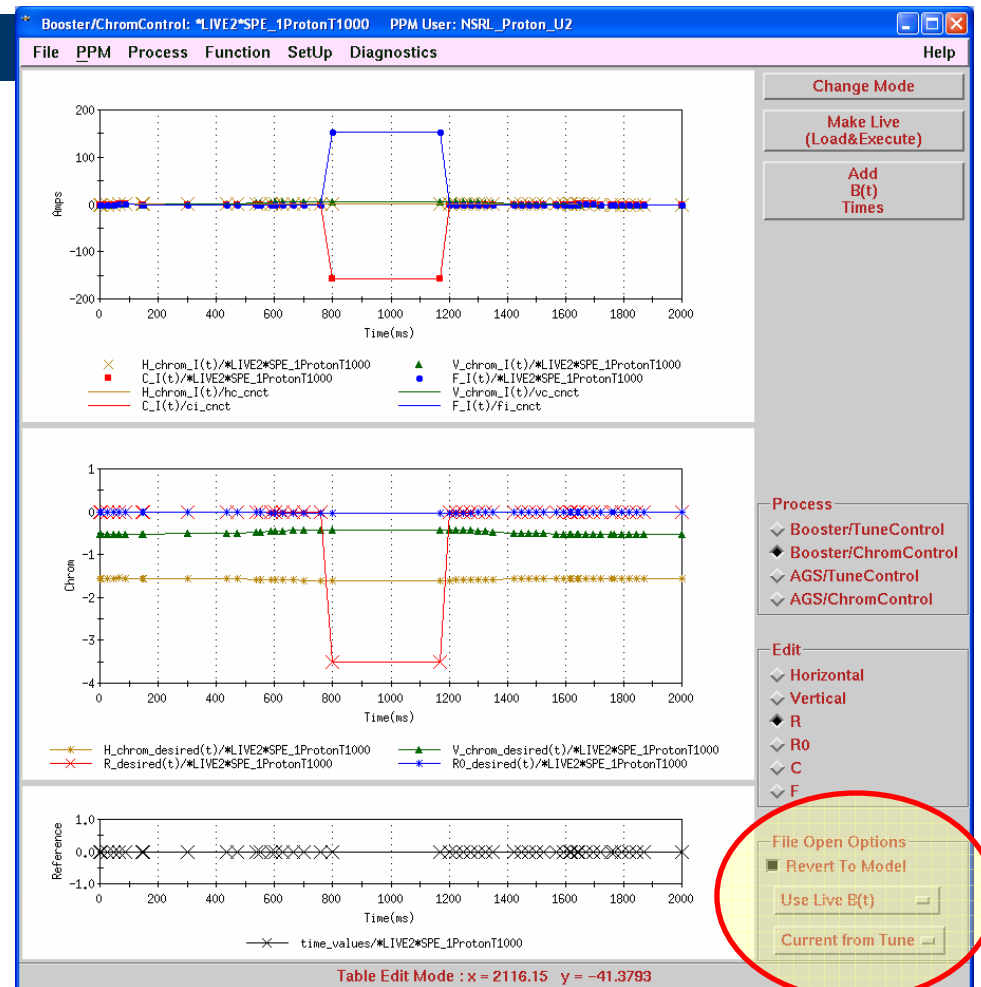
Scaling Tunes

- Tune functions tied to an underlying model of the Booster optics
- These functions must be *remodeled* due to change of the Booster main magnet
- Remodeling performed automatically when function is loaded, based on main magnet function



Scaling Resonant Sextupoles

- Recall that the resonant sextupoles are a set of four sextupoles used for slow extraction
- Remodeling of sextupole currents is similar to tune currents
 - Normally performed when a new function is loaded for a given main magnet function
- Sextupoles scale as the ratio of the square roots of the rigidities



Scaling of Transport Elements

- Transport elements (R-line) are scaled using the ratio of the rigidities
- Most quickly accomplished using the R-line magnet manager
 - Magnet manager converts magnet *strengths* (magnetic fields) to *currents* based on the desired *rigidity*
 - Note that hysteresis of 20° bend (RD1&2) may be required after application of magnet manager

The R-line Magnet Manager

- Check that present setting of rigidity matches current beam conditions
- Use **GetA** to place present currents into staged currents
- Change **bRhoS** to desired rigidity for energy change
 - New values of staged currents are calculated
- Use **commitA** to apply new currents settings (staged currents) into magnetic elements

The screenshot shows the NSRL/r_line_Magman application window. It features a menu bar (Page, PPM, Device, Data, Tools, Buffer) and a main data table. The table has columns for PSC Ado Name, Strength, Staged Current, Current, commit, Strengt, ScaleFa, PSC Setpoint, PSC Readback, PSC State, and Pol. The 'Current' column is highlighted in red. Below the table, there are input fields for 'bRhoS' (set to 12.15209) and 'Filename', along with 'load' and 'save' buttons. At the bottom, there are status messages and a 'Rigidity setting' label pointing to the 'bRhoS' field.

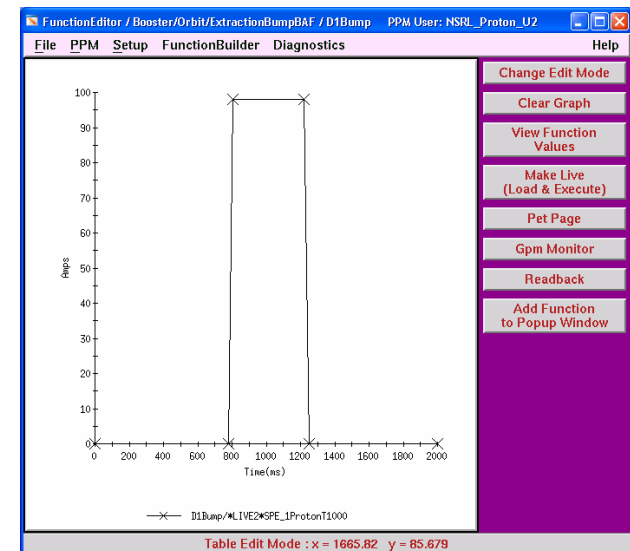
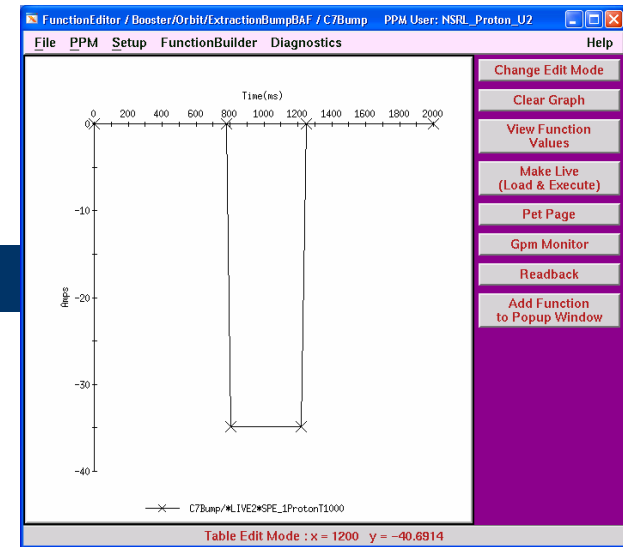
Annotations on the screenshot include:

- Present current in magnetic element**: Points to the 'Current' column in the table.
- Apply present currents to staged currents**: Points to the 'GetA' button.
- Send staged currents to all magnetic elements**: Points to the 'commitA' button.
- Current to be applied to magnetic element**: Points to the 'Staged Current' column.
- Rigidity setting**: Points to the 'bRhoS' input field.

PSC Ado Name	Strength	Staged Current	Current	commit	Strengt	ScaleFa	PSC Setpoint	PSC Readback	PSC State	Pol
bd6-sptm-ps-ps	0.17158	4906.128	635.133	commit	1	4441.932	4446.12	On	A	use P!
rp11_tdv1-ps	-0.00051	-5.003	-5.003	commit	1	-50.000	-50.1028	On	B	use P!
rd13_tdh2-ps	0.00000	0.000	0.000	commit	1	0.000	0.0292978	On	B	use P!
rq1-ps	0.20161	682.218	86.390	commit	1	669.985	671.751	On	B	use P!
rq2-ps	0.23427	792.501	100.620	commit	1	803.979	806.261	On	A	use P!
rd70_tdh3-ps	0.00000	0.000	0.000	commit	1	14.389	14.4035	On	A	use P!
rp73_tdv4-ps	0.00019	10.406	1.356	commit	1	0.000	-0.0982696	Stby	A	use P!
rarc20-ps	0.16842	2203.552	256.592	commit	1	2253.550	2302.1	On	A	use P!
rq3-ps	0.27114	917.185	116.735	commit	1	1070.993	1074.1	On	B	use P!
rq4-ps	0.26408	893.269	113.644	commit	1	964.961	972.7	On	B	use P!
rd137_tdh5-ps	0.00000	0.000	0.000	commit	1	0.000	-0.07019	On	A	use P!
rp140_tdv6-ps	0.00015	8.330	1.085	commit	1	5.215	5.573	On	B	use P!
roct1-ps	24.30182	1509.210	194.695	commit	1	1959.869	1963.1	On	A	use P!
rq5-ps	0.20594	696.853	88.276	commit	1	655.547	656.2	On	B	use P!
rd178_tdh7-ps	0.00003	1.585	0.207	commit	1	9.841	-0.0842311	Stby	B	use P!
rp181_tdv8-ps	0.00004	2.019	0.263	commit	1	1.500	1.500	On	B	use P!
roct2-ps	24.63639	1530.830	197.376	commit	1	1530.830	1530.830	On	A	use P!
rq6-ps	0.00000	0.000	0.000	commit	1	0.000	0.000	On	A	use P!
rq7-ps	0.13430	454.313	57.252	commit	1	454.313	454.313	On	B	use P!
rq8-ps	0.25426	860.033	109.348	commit	1	860.033	860.033	On	A	use P!
rd250_tdh9-ps	0.00046	25.427	3.305	commit	1	15.706	0.210578	Stby	A	use P!
rp253_tdv10-ps	0.00096	53.197	6.899	commit	1	33.790	34.8576	On	B	use P!

Scaling Extraction Bumps

- Extraction bumps (C7, D1, D4, D7, E1) are scaled according to the ratio of the rigidities
 - Determine rigidities from Gardner notes
 - Calculate ratio (greater energies require larger rigidities)
 - Multiply currents by the ratio
 - Set the extraction bumps using Function Editor



Scaling Extraction Septa

- Extraction septa at D3 and D6 are scaled similarly, using the ratio of the rigidities
 - D6 septum is generally straightforward adjustment
 - D3 may require scanning and adjustment after scaling

NSRL/Ring PPM User: NSRL_Proton_U2

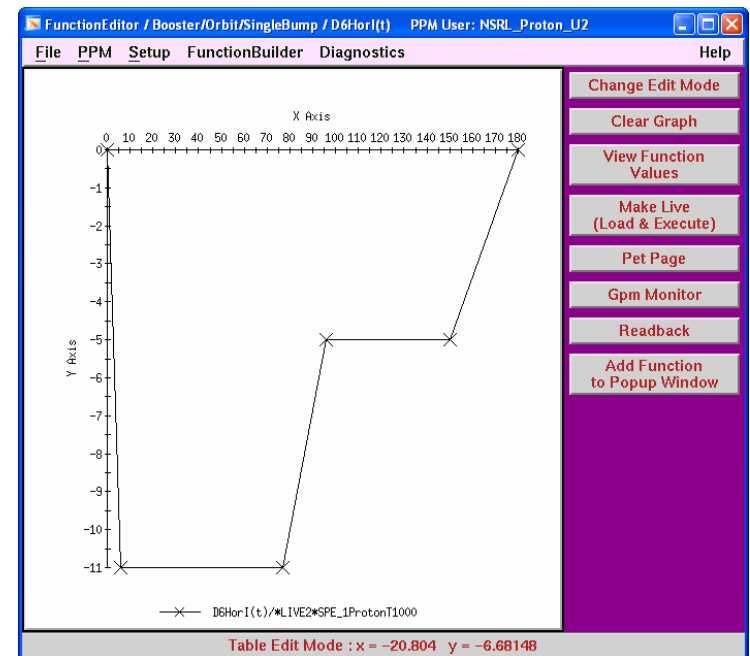
Page	PPM	Device	Data	Tools	Buffer	Help
Magnet						
		Dwell out(A)		Ctrl	Status	Faults
b-sxr1-ps		0		0n	0n	
b-sxr2-ps		0		0n	0n	
bc7-blw-ps		0		0n	0n	
bd1-blw-ps		0		0n	0n	
bd4-blw-ps		0		0n	0n	
bd7-blw-ps		0		0n	0n	Water Flow Fault, Phase Fault
be1-blw-ps		0		0n	0n	
Current(A) Setpt (A)						
bd3-sptm-ps-psc		3553.07	433.875	0n	0n	On, Unknown Pol
bd6-sptm-ps-psc		3002.12	2110.78	0n	0n	On, Unknown Pol
bd6-blw-ps		99.79	99.00	PolB		
Drives						
	Position	Control	Retract/Recal	Limit Sw	Lin Pot (mm)	
bd3-sptm Upstream	140300	140300	home	No	-23.34	
bd3-sptm Downstream	113600	113600	home	No	-18.05	
D6 Collimator	1	0	home	Retracted	2.14	
Flag/Foil Drive						
	2	2				

(1,2) "text" Nudge: 0 673

Tue Apr 15 13:50:24 2008: copying parameter values to buffer.
 Tue Apr 15 13:50:25 2008: Get and Async requests complete.

Adjusting Correction Elements

- Although changing energy at extraction, some injection problems may occur
 - Mainly related to the D6 septum remnant field and history
 - Retraining of D6 septum may be required
 - Hysteresis of D3 septum may also be required
 - Normally only needed when lowering extraction energy
 - Scaling of D6 corrector coil and/or D6 single dipole may be required
 - Tuning may be necessary to find optimal injection efficiency



Species Change

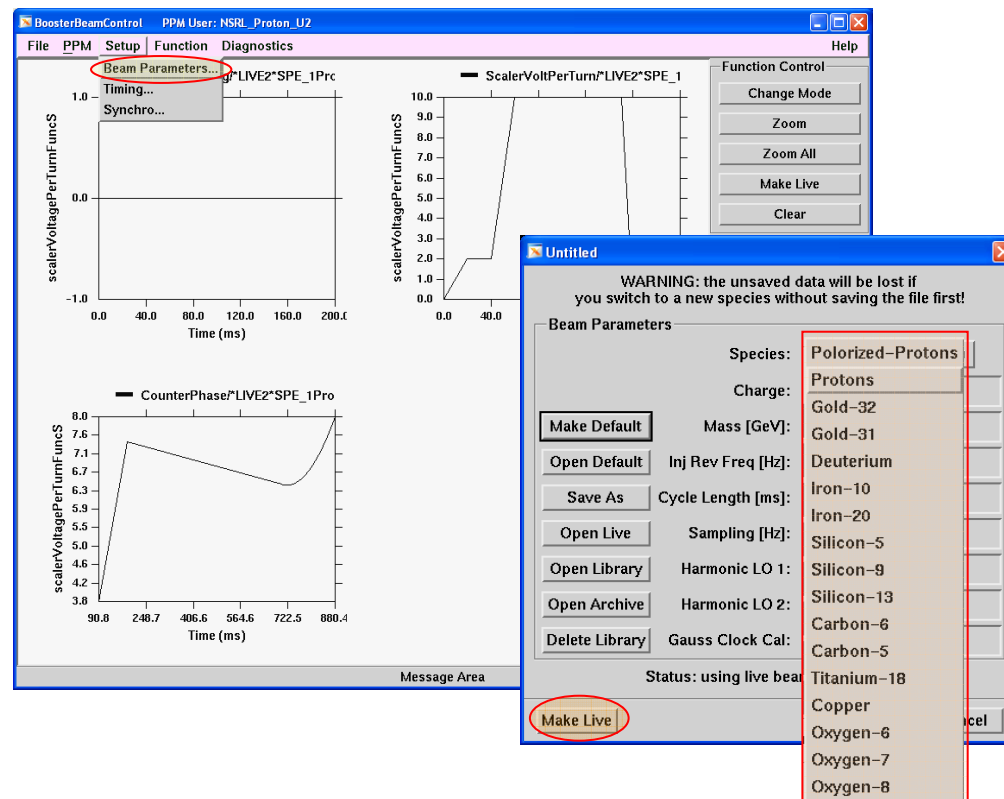
- When changing species, you are essentially doing both a species and an energy change.
 - Everything done with the energy change must be done as well as other tasks directly related to the change in species itself.

Loading Archives

- In general, many runs have been archived and could potentially be loaded
 - This must be done with care!
- TAPE-created archives are the most desirable archives to load
 - Created at specific, reliable points in the operations cycle
 - Created by documentation routines
 - Also created by NSRL Archive Creator

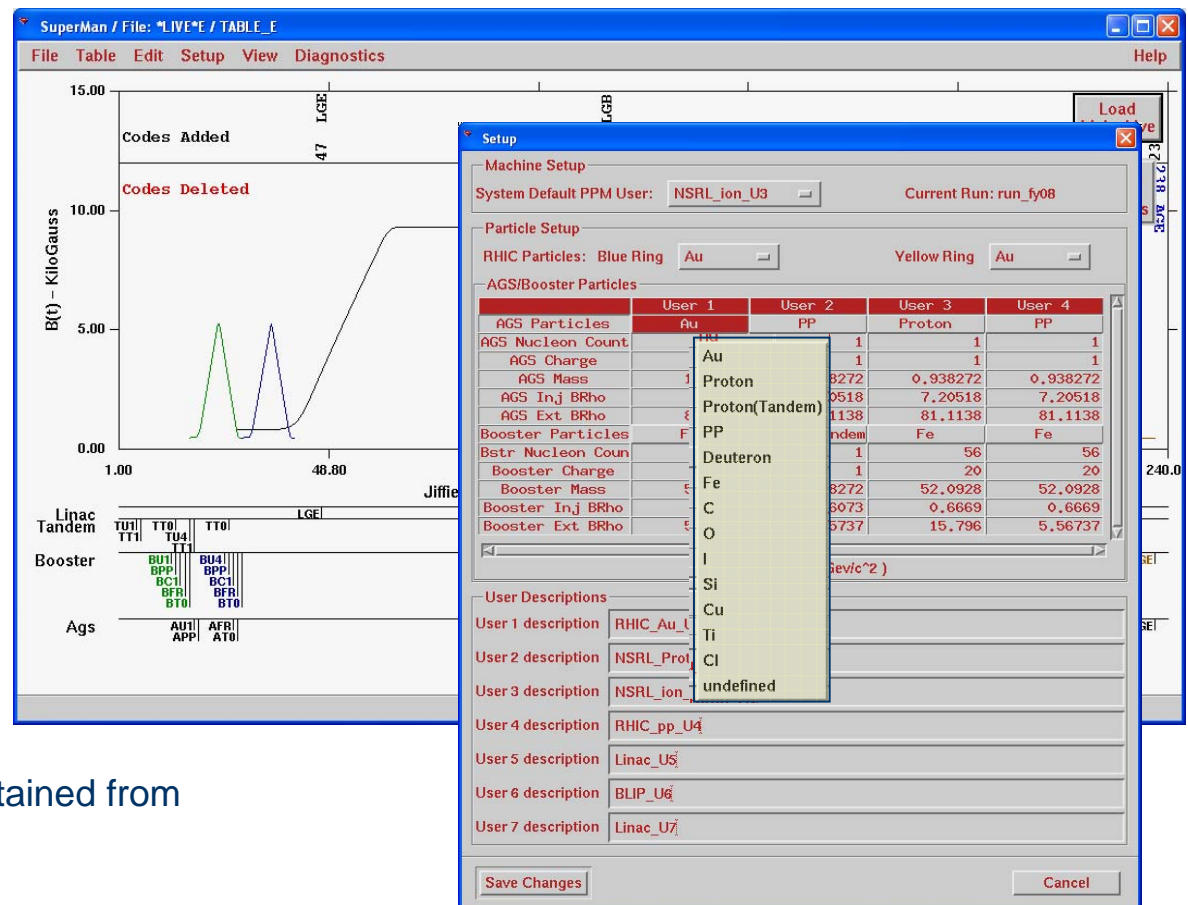
Loading RF Parameters

- RF parameters are loaded via BoosterBeamControl
 - Most parameters are available as presets



Setting User Parameters

- Species and energy parameters are set in SuperMan
 - Species are available as presets
 - Species parameters must be entered manually
 - Data can be obtained from Gardner notes

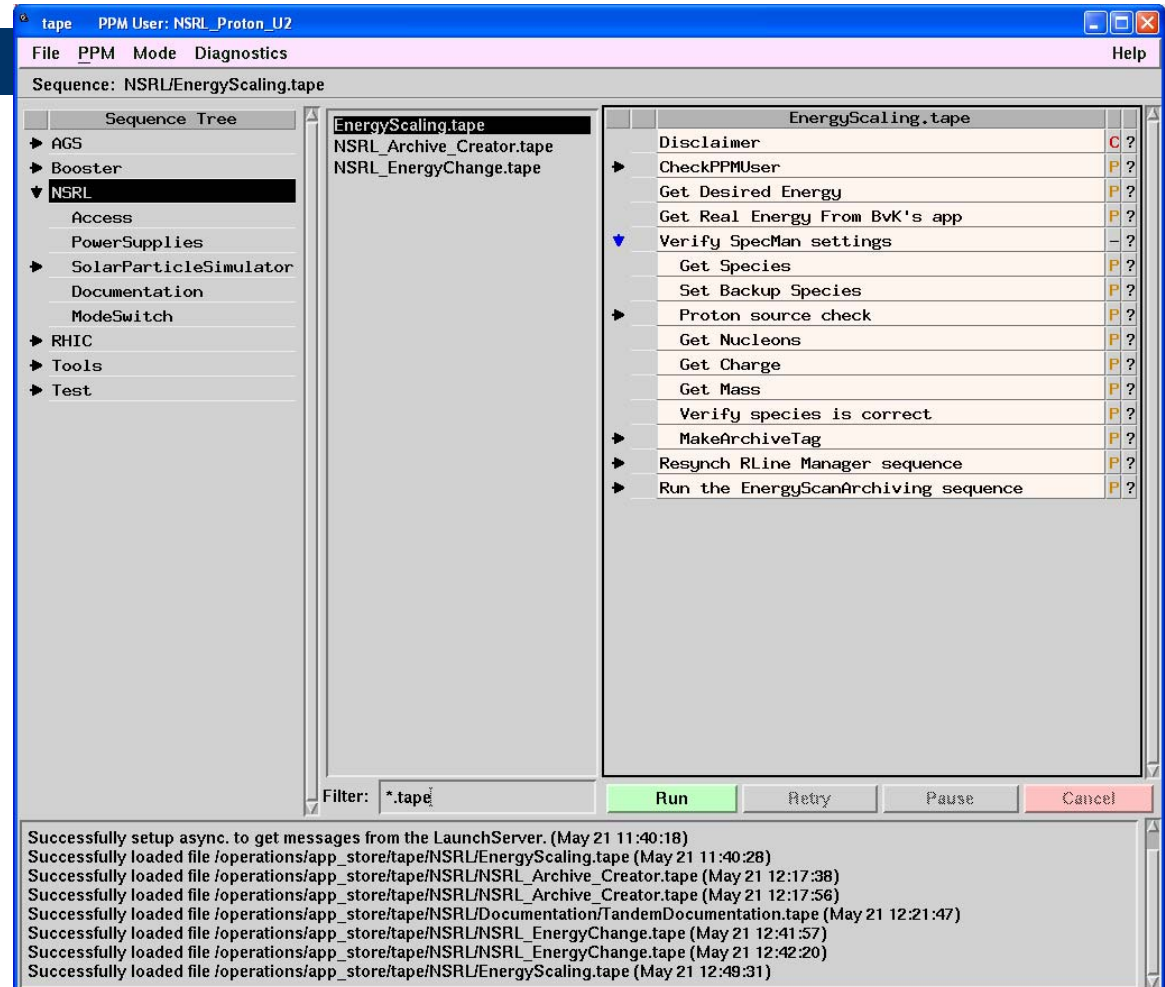


Using TAPE

- TAPE automates steps that have been described above
- TAPE allows for the following:
 - Archive creation
 - Energy/species scaling
 - Energy/species changes
 - Changing between preset archives

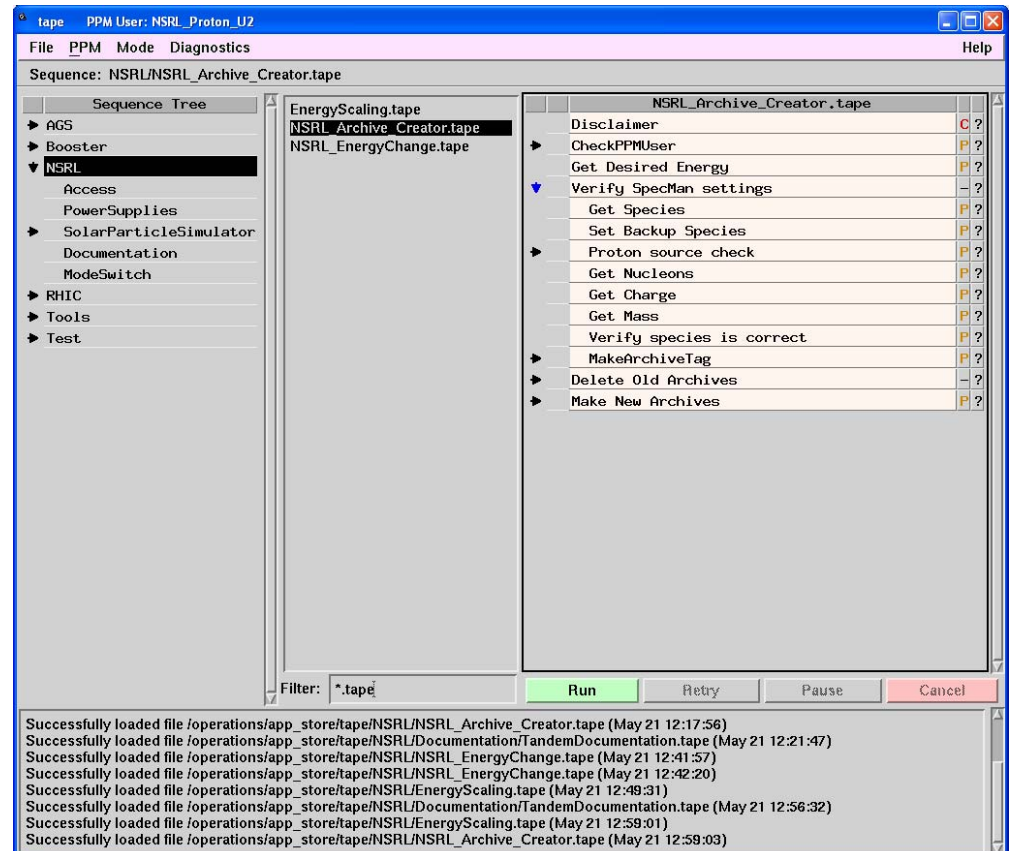
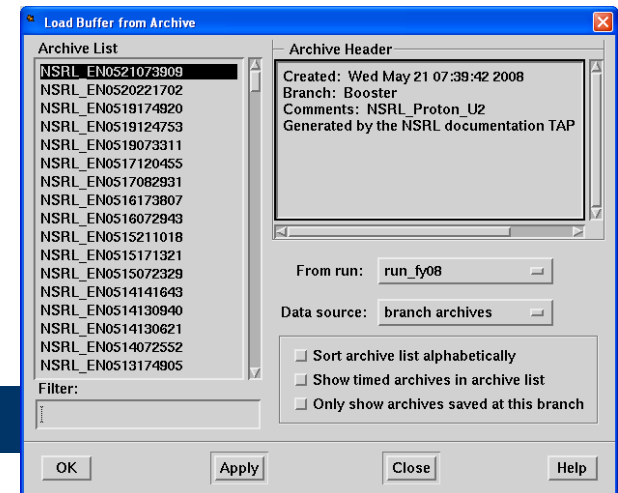
TAPE: Energy Scaling

- Energy scaling allows user to specify new energy
 - Used to scale from an existing, properly working (“good”) setup to a different energy
 - Species is not allowed to change
- Machine parameters are scaled to correct value



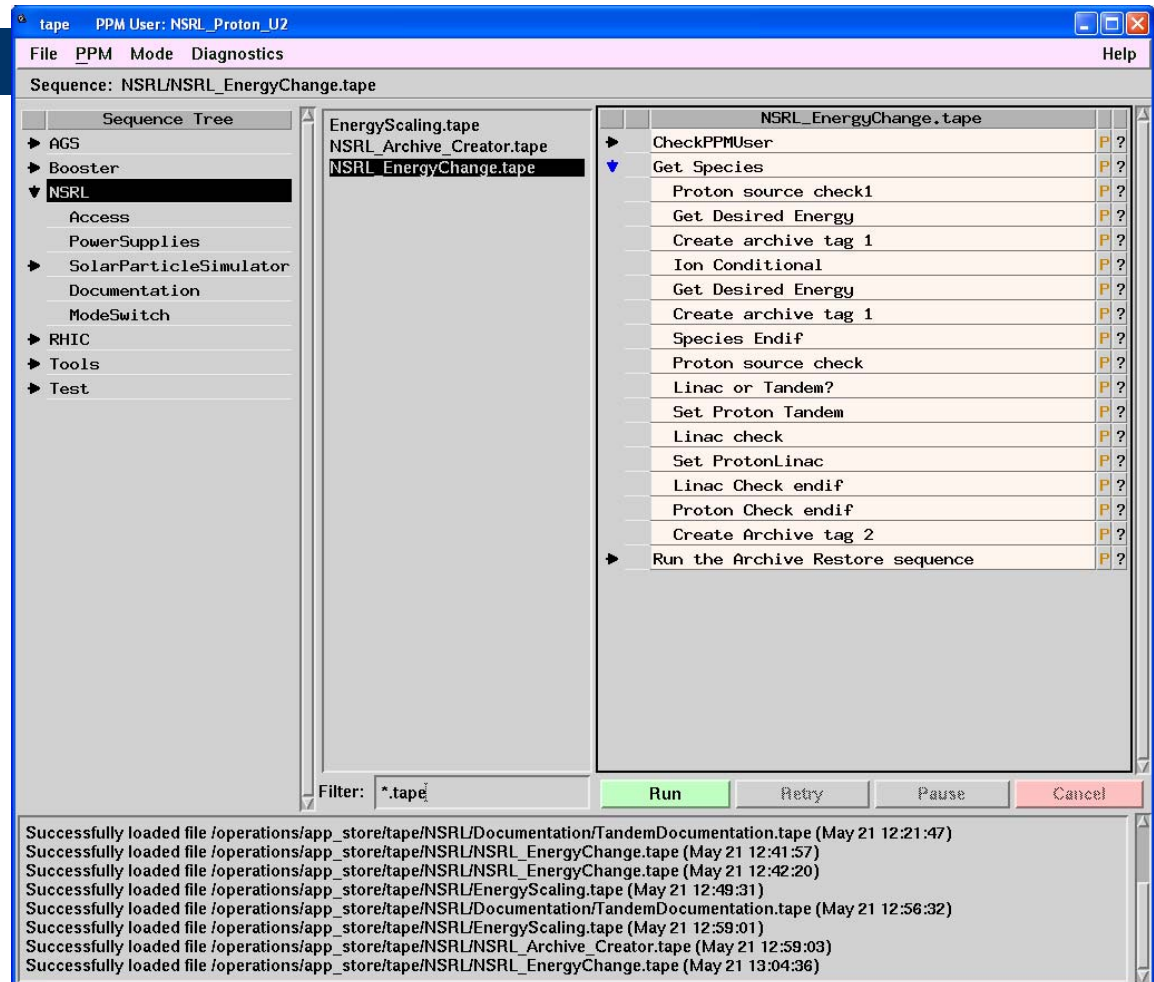
TAPE: Archive Creation

- Morning number create machine archives
- Archive Creator saves archives of a specific energy and species for future reference
- Allows for rapid cycling between setups through the NSRL Energy Change routine



TAPE: Energy Change

- NSRL Energy Change routine used to change between preset energies for a given species



Problems and Solutions Related to Energy or Species Changes

Symptom	Possible problem	Method for finding	Solution
No Injection	Transport from TTB	Examine pet	Load previously running values
No Injection	Inflector is wrong.	Examine pet	Load proper value.
No/Poor Injection	D6 fringe field	Observe injection on scope.	Tune D6 trim coil and or D6 single dipole magnet
No/Poor Injection or incomplete acceleration	Tune function wrong	Check Optics Control	Create and load proper function.
No acceleration	Gauss clock not on primary	Check pet and ADT	Put on Primary gauss clock.
No Acceleration No gap volts	Wrong Beam Parameters	Check in BeamControl	Load proper values.
No Extracted beam	Extraction tune wrong	Observe Extraction parameters on scope.	Adjust tunes as necessary.
No or poorly extracted beam	Extraction radius wrong	Observe spill parameters in virtual scope, intensity on GPM.	Adjust radial steering function.
Poor extraction efficiency	D3 septum at wrong or bad setting	Observe spill parameters in virtual scope, intensity on GPM.	Scan d3 septum.